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To: ADs, SDs, SCD

From: Director

Subject: Information and Data Needs for Ecosystem Management

DD: 6/15/94

The attached paper addresses a topic that is just now in its early stages of development within the Bureau of Land Management (BLM). The paper was developed to stimulate discussion on the topic. The result of these initial discussions have highlighted various factors that need to be considered in the development of the information and data set. The paper specially focuses on the topic from the resource managers point of view.

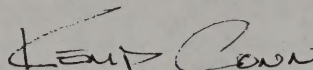
It is the Bureau's resource managers that are ultimately being charged to implement ecosystem management. Their success will, to a large degree, be determined by the information and data made available to them for decision-making. The makeup of the information and data will provide the picture of how ecosystem management gets applied.

Although the precise information and data sets are not yet known, the paper has begun the process by compiling descriptions of the general types that will be needed. A table is presented at the end of the paper which provides the initial data set descriptions based on the following questions:

1. What are the general types of management decisions that need to be made at each of the national, State/ecoregion, and local area levels?
2. What are the general types of information and data that are needed to support each of the management decisions?

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The paper contains a number of recommendations. We are making progress on some of these recommendations. Others I feel are worthy of consideration. I am requesting your assistance in conducting a management perspective review of this paper and its recommendations. We intend to revise the report based on your review. **Please submit your comments to AD-200 (Attention David Rosenberger) by June 15, 1994.**



Acting Assistant Director, ^{Kemp Conn}Land and Renewable Resources

1 Attachment

- 1- Information and Data Needs for Ecosystem Management (24 pp)

Information and Data Needs for Ecosystem Management

It is the great complexity of the subject matter of ecology that has thus far defeated most of our attempts to produce sweeping generalizations. We find all too often that our models and paradigms are contracted by the evidence, but we find ourselves unable to replace them with better.¹

INTRODUCTION

This paper addresses a process that is just now in its early stages of development within the Bureau of Land Management and other resource management agencies of the Federal government. Thus, this paper is not designed to provide the definitive pieces to an information and data puzzle that, when properly assembled, would show the picture needed for ecosystem management. Rather, this paper is intended to stimulate discussion of how best to determine the information needed for effective ecosystem management. Nonetheless, by keeping a focus on the theme surrounding this title and continuing to ask its question does persist in stimulating policy and management discussions. The subject matters of these discussions have highlighted various factors that will need to be considered in the development of the information and data set. The content of these discussions have been carried into the general organization and substance of this paper.

Ecosystem management is a committed goal of the Bureau of Land Management. Information and data are the commodities of exchange between the resource managers, technical specialists, research scientists and the general public enabling them to communicate and achieve its goal. Further, the Bureau is a "corporation" with legal responsibilities for the management of more than 270 million acres of land and associated renewable and nonrenewable resources. For these reasons, this paper specially focuses on information and data needs for ecosystem management from the viewpoint of the Bureau's resource managers at all corporate levels.

Critiquing past practices and policies is a relatively simple task for one has the benefits of hindsight -- examples to draw upon, technical information, and statistical data. Providing constructive assistance to move forward is a much more difficult and time consuming task requiring the inputs and thoughtful consultations from as many sources as possible. This paper is directed towards the latter.

EXECUTIVE SUMMARY

It is the Bureau's resource managers that are ultimately charged with the responsibility of implementing ecosystem management. Their success will, to a large degree, be determined by the information and data made available to them for decision-making. Also, the makeup of the information and data will provide the picture of how ecosystem management is applied. For these reasons, **the Bureau should establish an Ecosystem Management Implementation Team to coordinate and direct the development of programs for constructing the information and data sets needed by management.**

Ecosystem management is not a "new" concept. The term ecosystem was first introduced in 1935 referring to the interaction of all living and nonliving factors in the environment. However, the Bureau's commitment is unique because it is being implemented across the entire national geographic scale; and is being administered throughout its resource management programs. The experiences gained by similar initiatives could be helpful. The Bureau should, therefore, identify and study these initiatives to learn the strengths and weaknesses of both their management and scientific merits (Page 5).

The Bureau should consider establishing a capability for developing long-range socioeconomic forecasts and strategic planning. These forecasts could aid in the evaluation of long-term budget priorities, changing personnel requirements, and identification of research needs for consideration by the National Biological Survey. Evaluation of long-range projections and forecasts could potentially serve to forestall "train wrecks" (Page 7).

Scientists in several Federal agencies have developed various schemes for scaling ecosystems. The importance of their work to the Bureau cannot be overemphasized. Linking ecosystem scales with management hierarchies provides a basic framework to which all can relate. The Bureau should evaluate the various scaling options to determine which best represents the Bureau's renewable and nonrenewable resource interests. In the absence of an ecosystem scaling system, it is unlikely that Bureau managers can implement ecosystem management consistently (Page 13).

A key component to the Bureau's implementation of ecosystem management will be the establishment of results oriented performance measures at all levels of the organization. These performance measures represent a principal class of information and data needed by the Bureau's resource managers. For these reasons, the Bureau needs to ensure that it develops performance measures that specifically evaluate ecosystem management strategies and objectives (Page 14).

The Bureau, as part of its FY95 budget, has expressed its commitment to bring noncommodity resources on par with commodity resources. The inventory requirements of FLPMA 201(a) also require the Bureau to prepare and maintain on a continuing basis an inventory of public lands and their resources and values (emphasis added). The activities underway in several other organizations will likely be of assistance to the Bureau in meeting

its resource valuation commitments. The Bureau should develop formal and informal ties with organizations that address the valuation of natural resources to gain improved understanding of ongoing resource valuation activities. The Bureau should also specifically request the National Biological Survey to assist in the development of appropriate measures of BLM's resource values for use at the national, ecoregion, and local area levels (Page 15).

In complex, multiuse systems, management is widely divested among agencies and political jurisdictions. Interagency coordination of management actions is critical. Coordination is required for establishing common ecosystem management goals, strategies and plans; and the conduct of joint assessments. Such efforts would aid in the development of common data, avoid unnecessary duplication, reduce assessment costs, and increase the range of technical and scientific expertise. Problems of incompatible data sets, different findings and conflicting conclusions are minimized (Page 16).

Although the precise information and data sets needed for implementing ecosystem management within the Bureau are not yet known, it is reasonable to begin compiling descriptions of the general types that will be needed. These descriptions have been compiled in Table 1 (Page 19). The descriptions have been developed based on the following questions:

1. What are the general types of management decisions that need to be made at each of the national, ecoregion, and local area levels?; and,
2. What are the general types of information and data needed to support each of the management decisions?

BACKGROUND

The term ecosystem was first introduced by Tansley in 1935, which he defined to mean a system resulting from the interaction of all the living and nonliving factors of the environment. Webster defines it to mean a complex of ecological community and environment forming a functioning whole in nature. Golley² refers to ecology as the study of interactions and relationships between living systems and the environment. Odum³ considers ecological systems as units of nature in which living and nonliving substances interact with the exchange of materials between the living and nonliving parts. Thus, an ecosystem is a functional unit of ecological study consisting of organisms (including man) and environmental variables of a specific area. The term "eco" implies environment; the term "system" implies an interacting, interdependent complex⁴. The size and boundaries of ecosystems are subjective based on the scale of interdependent ecological complexes of interest.

The growth of ecology and the study of ecological systems have resulted in an evolution of technical specialties. Some are interested in wildlife species and their natural history, others the complexities of entire ecological systems, and still others the problems of man and the environment using ecological principles. Thus, the study of ecological relationships can be considered from two main viewpoints. First, one may view all the interrelationships of a single species of organism, viewing its ecology as a set of adaptations. This approach is known as autecology. The phrase "the ecology of wild horses" implies an autecological viewpoint. Second, one may also view these relationships as a whole -- as they exist within an ecosystem. Such an approach sees ecology as a property of a community of organisms such as that within the forests of the Pacific Northwest or the North American prairie biome. This approach is known as synecology. The former approach is reductionistic and the latter is holistic -- both necessary for total ecosystem understanding.

A precursor to the current ecosystem approach and ecosystem management was the systems approach and systems ecology. Basically a holistic methodology, the systems approach evolved to solve individual problems in the context of the total system of interest⁵. Early success in quantifying ecosystem energy flow, led by Howard Odum and others, showed the feasibility of addressing total ecosystem problems⁶. Total ecosystem studies were greatly stimulated by the advent of the International Biological Programme (IBP). The United States initiated a series of ecosystem studies through the IBP Biome Programs. These programs proposed major interdisciplinary studies that involved hundreds of scientists and dozens of research specialties.

One of the earlier attempts to specifically apply ecosystem management was that conducted at Lake Monona⁷, a lake in northeastern Wisconsin experiencing overuse from recreational activities, lakeshore development, and extensive dredge and fill activities. Public concern over swimmer's itch and nuisance aquatic vegetation prompted the development of a conceptual model for the management of the lake's ecological system. An interdisciplinary team, of local citizens, an economist, an aquatic chemist, a terrestrial biologist, a recreation

resource specialist, a political scientist, and a resource development specialist were used to implement the management model. Such an interdisciplinary team approach represents one of the basic precepts of ecosystem management.

Woolcott⁸ described the application of an ecosystem approach to the evaluation of the ecological impacts of thermal loading on a Piedmont River. Likens⁹ characterized a microcosmic study of the aquatic ecology of Mirror Lake and its environments illustrating many of the factors considered in an ecosystem approach with primary focus on biogeochemical factors. In 1978, a board of the International Joint Commission¹⁰ explained the scope and implications of an ecosystem approach for managing transboundary problems in the Great Lakes basin. An Agreement between the United States and Canada was subsequently ratified incorporating an ecosystem approach for the management of water quality in the Great Lakes basin.

The above discussion highlights the extensive foundation upon which ecosystem management has thus far evolved. Although ecosystem management is not a "new" concept, its application has been limited to local and regional geographic scales. Recently however, the Bureau of Land Management, along with several other Interior Bureaus and federal agencies, have expressly stated their commitment to incorporate ecosystem management into their respective stewardship responsibilities^{11,12,13}. The Bureau of Land Management has, for example, articulated its ecosystem management to mean:

the integration of ecological, economic, and societal principles to manage biological and physical systems in a manner that safeguards the long-term ecological sustainability, natural diversity, and productivity of the landscape.

The commitment by the Bureau and the other federal agencies is unique in several important aspects. First, it represents the initial effort by Federal resource agencies to implement ecosystem management across the entire national geographic scale. Secondly, it is being administered as a management principle throughout all the Bureau's programmatic resource management, human resource management, information resource management, and business practices. An ecosystem management effort of this magnitude and extent should draw upon the experiences gained by other initiatives, as exemplified by those above. *The Bureau should continue to identify other ecosystem management and related efforts to study the respective strengths and weaknesses of both their management and scientific merits.*

CORPORATE CONSIDERATIONS

The Bureau of Land Management is essentially a "corporation" with legal responsibilities for the management of more than 270 million acres of land and associated renewable and nonrenewable resources held in public trust. As a "corporation," it is important that the leadership and staff that are engaged in sponsoring and implementing ecosystem management understand clearly their mission, functions and overall direction

towards establishing that goal. *To that end, the Bureau should consider reevaluating its existing Enterprise Data Model¹⁴ to clearly identify and articulate the major business activities and information that managers need in the performance of these activities.* The information that follows addresses several factors of general consideration.

Managing Ecosystems

Scientific inquiry and the advancement of knowledge is a continuum, whereas, management decision making represents the moment with consequences carried into the future. Webster states that to manage means to conduct one's business affairs in the achievement of a purpose or objective. Thomas¹⁵ et. al. discusses the management of ecosystems and the need for developing management objectives for ecological systems. To illustrate, they proposed an ecosystem management objective for the Great Lakes Basin as follows:

To restore and secure the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem as a multiuse resource with full commitment to renewable resource management principles, to provide for the requirements of society for food and drinking water, human health, shelter and energy, industrial and commercial opportunity, and cultural and recreation.

To achieve the management objective, Thomas et. al. note that obstacles standing in the way need to be identified and strategies developed to overcome them. Obstacles then represent management issues for which long-range plans or strategies are developed to address. Thus, long-range strategies lead to the attainment of objectives. Thomas et. al. represent their point by discussing toxic chemicals as an issue which stands in the way of achieving their proposed ecosystem management objective for the Great Lakes basin. Strategies to attain the objective are addressed through source elimination, technology, and interim control measures.

Similarly, the Bureau of Land Management needs to reassess its mission statement to specifically incorporate the goals of ecosystem management as expressed by the ecosystem management concept paper. Recognizing the broad, national scope of the mission statement, it may also be appropriate to develop specific ecosystem management goals for each ecoregion of management concern to the Bureau. Management issues such as rangeland health, noxious weeds, anadromous fish, and forest health can be viewed from both national and ecoregional perspectives. *Appropriate long-range strategies then need to be established that conform to the Bureau's revised mission statement.* Issues like rangeland health which transcends several ecoregions may necessitate tailoring specific strategies to conform to the ecosystem management goals for the respective ecoregions. Thus, from the resource

managers' point of view, the management goals and strategies need to be identified prior to designing the resource inventories and the types of data to be collected.

Management entails not only addressing the issues of today but also developing socio-economic forecasts and long-range resource and environmental projections of future potential management issues. For example, Thomas et. al. noted that management goals and issues are influenced by changing public attitudes and expectations, fiscal restraints of governments, and changing patterns of regional economic growth. Evaluation of long-range projections and forecasts could potentially serve to forestall "train wrecks."

The Bureau of Land Management should establish a capability for developing long-range forecasts and strategic projections. These forecasts could serve to facilitate proactive management for the evaluation of long-term budget priorities, changing personnel requirements, and identification of research needs for consideration by the National Biological Survey. Such an effort is consistent with the requirements of the Government Performance and Results Act of 1993 to develop 5-year strategic plans; and the weighing of long-term versus short-term benefits to the public of plans prepared under FLPMA.

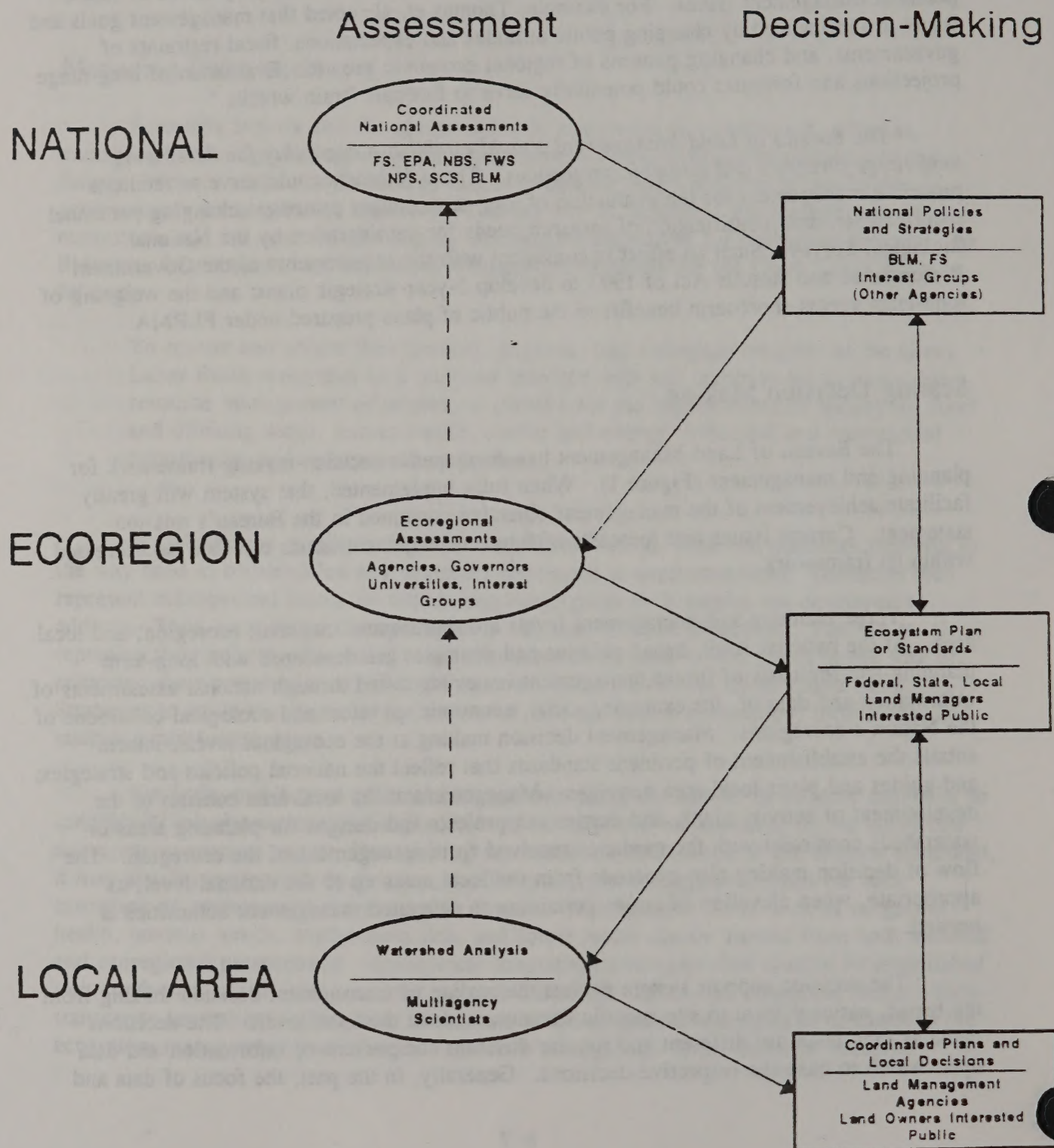
Scaling Decision Making

The Bureau of Land Management has developed a decision-making framework for planning and management (Figure 1). When fully implemented, that system will greatly facilitate achievement of the management objective contained in the Bureau's mission statement. Current issues and forecasts of future management issues can then be addressed within its framework.

Three planning and management levels are represented: national; ecoregion; and local area. At the national level, broad policies and strategies are developed with long-term planning and forecasts of future management issues identified through national assessments of information and data of, for example, social, economic, physical and ecological conditions of the Nation's ecoregions. Management decision making at the ecoregional levels, in turn, entails the establishment of pertinent standards that reflect the national policies and strategies; and guides and plans local area activities. Management at the local area consists of the development of activity plans, and carries out projects and designs for planning areas or watersheds consistent with the guidance received from management of the ecoregion. The flow of decision making also proceeds from the local areas up to the national level, as appropriate, when elevation of issues pertaining to delegated management authorities is needed.

The decision support system depicts the scaling of management decision making from the broad, national level to site specific decision made at the local levels. The decisions made at each level are different and require different components of information and data upon which to base the respective decisions. Generally, in the past, the focus of data and

Figure 1. Decision-Making Framework for Ecosystem Management



information collection has been largely based on the needs at the lowest level, and data aggregated for the larger scales. The respective management levels each represent distinct user groups for which specific sets of information and data need to be identified and developed for implementing ecosystem management.

Scaling Information and Data

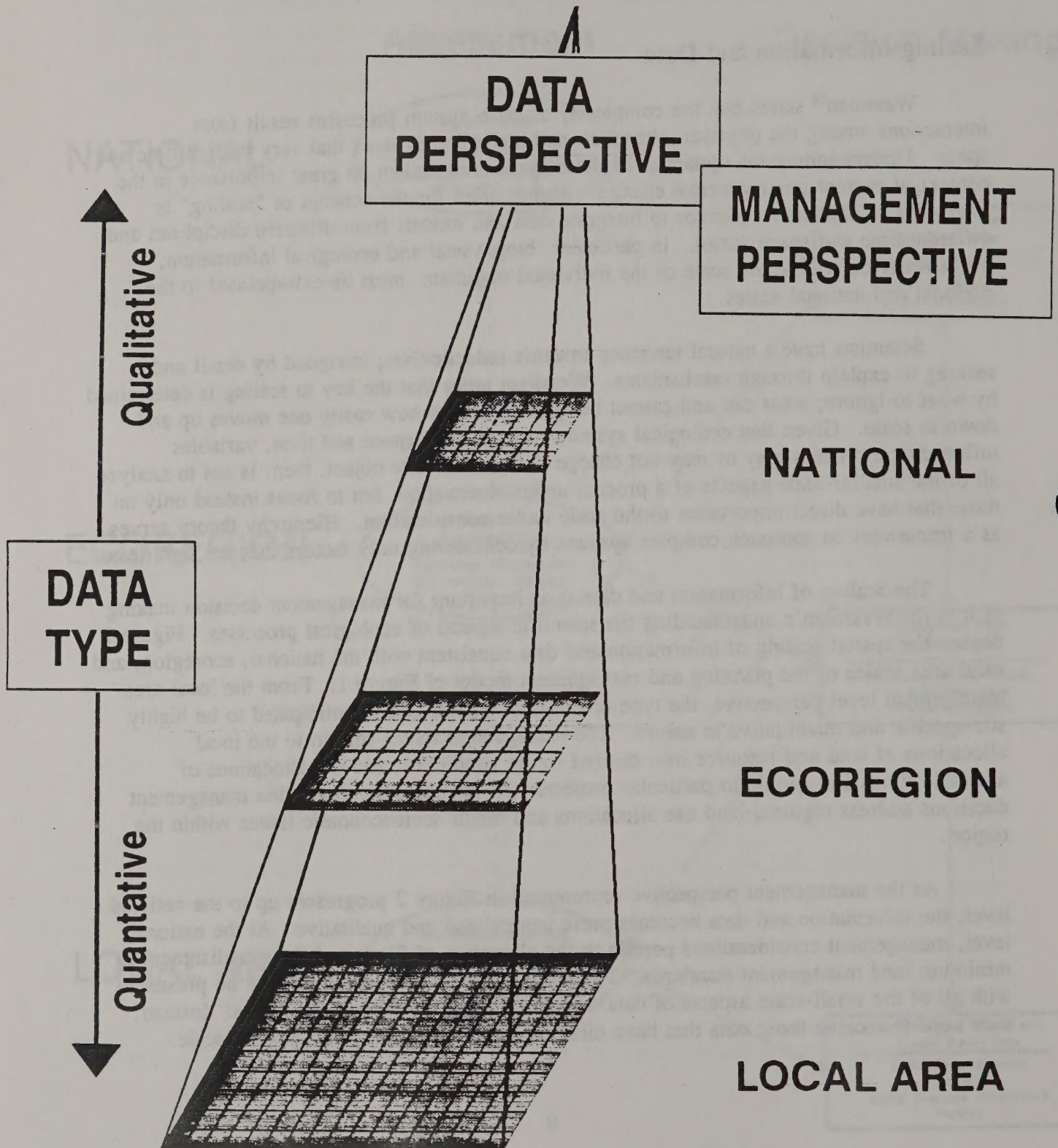
Wessman¹⁶ states that the complexity of earth system processes result from interactions among the physical, chemical, and biological systems that vary both in time and space. Understanding the dynamics of these systems has taken on great importance in the context of current environmental change. Appreciation for the concept of "scaling" is increasing as scientists endeavor to integrate data and models from different disciplines and different time and space scales. In particular, biophysical and ecological information, intrinsically derived at the scale of the individual organism, must be extrapolated to the regional and national scales.

Scientists have a natural tendency towards reductionism; intrigued by detail and seeking to explain through mechanisms. Wessman notes that the key to scaling is determined by what to ignore; what can and cannot be ignored affects how easily one moves up and down in scale. Given that ecological systems are scaled in space and time, variables influencing a process may or may not change with scale. The object, then, is not to analyze all of the smaller-scale aspects of a process under observation, but to focus instead only on those that have direct importance to the scale under consideration. Hierarchy theory serves as a framework to approach complex systems by considering only factors that are significant.

The scaling of information and data is as important for management decision making as it is for Wessman's understanding the scientific aspects of ecological processes. Figure 2 depicts the spatial scaling of information and data consistent with the national, ecoregion, and local area scales of the planning and management model of Figure 1. From the local area management level perspective, the type of information and data is anticipated to be highly site-specific and quantitative in nature. The management issues pertain to the local allocations of land and resource use, desired future conditions, and the allocations of available funds and people to particular projects. At the ecoregion level, the management decisions address regional land use allocations and major socioeconomic issues within the region.

As the management perspective represented in Figure 2 progresses up to the national level, the information and data becomes more generalized and qualitative. At the national level, management considerations pertain to the allocation of funds and the establishment of minimum land management standards. Therefore, national managers need not be presented with all of the small-scale aspects of data under consideration within local areas. Instead, they need to receive those data that have direct importance to their management scale.

INFORMATION AND DATA NEEDS FOR ECOSYSTEM MANAGEMENT



Historically the Bureau's Washington Office has relied on a variety of sources for its information and data needs. These sources included budget submissions, lands and mineral case-related statistics, specific resource-related data, and special requests. The value of the information was variable, depending on the specific need. Under ecosystem management, it may be of less value since it historically has been presented either on a state by state basis (i.e., political or administrative boundaries) or on an issue basis such as desert tortoise management. Often issue driven information can be quite detailed once it becomes aggregated. However, from an ecosystem management perspective, it is often too narrow in scope for use beyond the specific issue.

A Scaling Case Example

Cleland¹⁷ et. al. presents a case study for a hierarchical, multifactor ecological classification and inventory system for the Huron-Manistee National Forest in northern lower Michigan. Although the scope of the case study is limited to a relatively small geographic area, it is presented here to illustrate the differences in the scientific information and data obtainable for use in making different levels of decisions at three scaler levels. The Bureau's management of ecosystems at the three scaler levels depicted in Figures 1 and 2 will necessitate the availability of pertinent scientific information and data for these levels. At the macro scale, data from weather stations and satellite imagery were used to identify climatic gradients. Climatic-gross physiographic boundaries were drawn on a map at a scale of 1:100,000. Relationships between climate, landforms, and associations of forest types were evident at this scale. Satellite imagery showed conifer forests dominant in outwash plains nested within colder areas, whereas oak forests dominated in equivalent landforms and soils within warmer areas. Climatic stressors operating at higher spatial scales constrained potential successional pathways within landforms, and affected the distribution of plant communities at the mesoscale.

Mesoscale levels of the ecological classification were developed by delineating landforms on areal photography at a scale of 1:60,000. Patterns in overstory composition and soil parent material were checked in the field, and a preliminary classification was formulated. Findings from fine-level investigations, including intensive field data collection, were used to further characterize landform units and evaluate interrelationships. For example, mesic ecosystems underlain by loamy soils typically support fire intolerant forest types in Michigan. Comparable mesic ecosystems lying adjacent to or nested within landforms with historically high fire frequencies, however, were initially regarded as an unstable sere, or an anomaly. Investigating the system suggested that mesoscale fire-landform interactions have maintained these local ecosystems through time.

At the local scale, data on soils, substrates, ground flora, understory and overstory were collected using a random stratified sampling procedure. Initially, undisturbed, late successional forest types were examined to identify ecological potentials and interrelationships. Early seres, regenerating forests, and red pine plantations have been sampled since. Data were analyzed using a battery of numerical methods. Multifactorial

classification units, called ecological landtype phases (ELTP's) were developed using numerical and conceptual models, and verified using field techniques. Follow-up studies indicate that there are significant differences among ELTP's in both vegetative structure and ecosystem function. National Forest lands are being inventoried at scales of 1:15,840 for project level planning and management.

Cleland et.al. concludes that, from a practical point-of-view, ecosystem management involves placing elements that we have traditionally managed, such as commercial tree species or popular game species, into a broader context in which they are considered along with values that exist for all ecosystems (e.g., their history, complexity, beauty and cultural significance) This more comprehensive approach does not mean that utilization of natural resources to meet human needs is being diminished. On the contrary, understanding and protecting ecosystem processes is essential to ensuring a lasting supply of the materials and commodities that people require.

Ecosystem Scaling Options

As noted earlier in this paper, the relative size and boundaries of ecosystems is depends on the ecological complexes of interest. The distribution and vigor of wildland vegetation and the animals occupying these ecosystems are largely regulated by energy, moisture, nutrient and disturbance gradients. These gradients, in turn, are influenced by climate, physiography, soils, hydrology, flora, and fauna.

Bailey¹⁸ states that it is important to link ecosystems with management hierarchies. He does not suggest that three levels of ecological partitioning are everywhere desirable; there could be two or nine depending on the kind of question being asked and the scale of the study. However, he does consider it advantageous to have 'a basic framework to which all can relate and between which other units can be defined as required.

Jensen¹⁹ points out that ecological units may vary in detail depending on management objectives and the types of issues being addressed. He notes, for example, that ecological units may be broadly defined to assist corridor analysis of animal species with large home ranges or more narrowly defined to facilitate plant succession pathway predictions following prescribed burning. He recommends developing an analysis hierarchy which describes the type of issue to be addressed and the appropriate level of ecological unit stratification required to address each issue before undertaking an ecosystem analysis effort.

Ratti and Giudice²⁰ evaluated different regionalization schemes for scaling the natural variation in ecosystems. They divided the schemes into (1) ecological-regionalization systems that are based on several interacting-environmental characteristics and (2) land-classification systems that are based on a single physiographic or environmental characteristic. Noting that the importance of any single factor varies among regions, they recommended use of a national framework based on multiple-environmental characteristics.

The importance of regionalization scaling to the Bureau's ecosystem management cannot be overemphasized. This does not mean that a redefinition of political and administrative boundaries is required for implementing ecosystem management. Instead, it is important from the standpoint of providing the framework around which both the data and management perspectives of Figure 2 are developed. The regionalization scale, in part, provides the basis for the ecological assessments and political interactions that need to be addressed in the planning and management decision support system of Figure 1.

The Bureau of Land Management should proceed expeditiously to evaluate the merits of existing ecosystem scaling options to determine which of these options best represents its natural resource trust interests. The evaluation should consider all Bureau resources (aquatic, terrestrial, and geologic) weighing them against the scaling options. The purpose of this evaluation should be directed towards assisting in the formulation of an internal Bureau position on available ecosystem scaling options being advanced by the U.S. Forest Service, Environmental Protection Agency and others. Furthermore, adoption of a national framework for ecosystem scaling among Federal agencies could facilitate the development of common interjurisdictional management objectives for common ecosystems.

MANAGEMENT CONSIDERATIONS

In addition to the above corporate considerations, resource managers also have several general factors that need to be considered in the development of information and data for ecosystem management. These factors include: performance measures, decision making risk, resource economics, societal interactions, and interagency resource coordination. These factors help shape the "management" half of ecosystem management.

Performance Measures

The Bureau has traditionally measured its output in units such as the number of miles of constructed fence, millions of board feet of harvested timber, and number of animal units months of livestock grazing. These traditional measures fulfilled the needs for which they were intended. However, the Bureau's management objectives have evolved beyond that which the traditional measures were designed to address. As a result, other measures need to be developed to adequately provide resource managers with the ability to evaluate the Bureau's progress in achieving the current management objectives. Additional measures need to be established to gauge the level of success attained by the management strategies put in place to reach the objectives. (See above discussion on managing ecosystems.)

The Bureau's performance measures will need to consider time as a controlling element for evaluating expected results and management strategies. Some ecosystems will respond quickly to management changes, while others may require decades to show desired responses and results.

A key component to the Bureau's implementation of ecosystem management will be the establishment of results oriented performance measures at all levels of the organization. These performance measures represent a principal class of information and data needed by the Bureau's resource managers. *For these reasons, the Bureau needs to ensure that it develops performance measures that specifically evaluate ecosystem management strategies and objectives.*

Decision Making Risk

Management entails decision-making. This decision-making necessitates the management of risk. The consequences of incorrect decisions can extend long into the future. Minimizing these risks then entails an evaluation of all pertinent facts and figures. As the percentage of pertinent facts and figures increases, the lower the likelihood of an incorrect decision. Optimally, managers should wait to make decisions when all information is available. The constraints of time and costs associated with the collection of information must, however, be factored into the decision making.

The decision-maker must evaluate the probability of making the correct decision with say 60% of the pertinent facts available balanced against the time and cost of obtaining additional percentiles of information. Generally, the marginal benefits of each additional percentile decreases as the marginal cost of each increases. Thus, the cost of obtaining an additional five percent of information to move the decision making level to 65% may be less than the cost of the next five percent to reach 70%. Getting from 97% to 98% could potentially pose a much greater cost than all the other costs combined. Further, the lapse in time needed to collect these last increments of data could also mean that they are no longer relevant to the earlier data.

In other words, a thorough assessment of Bureau lands to collect all relevant and appropriate information and data for ecosystem management will be constrained by time and cost factors. For single and relatively small-scale inventories, a sound statistical design for subsampling information and data can reasonably improve the confidence levels of decision making pertaining to the area assessed. Risk management at the ecoregion level (see Figure 2) may entail determining the number of local area grid cells to assess to form a satisfactory picture of the entire ecoregion. The order in which the area assessments are conducted (grid cells filled in) may be of importance. Also, the decision making risks for the management of those areas (grid cells) for which assessment have not been performed may be reduced by the order in which assessments are performed (i.e., grid cell A is comparable to grid cell B).

The Bureau's inventory and assessment programs need to include both resource managers and technical specialists in the development of their design. The purpose of such involvement should, to the maximum extent possible, ensure that the activities meet both management, technical and statistical needs; and considers risk management. The process

used in the BURN project²¹ should be evaluated for its merit and use throughout Bureau inventories and assessments.

Resource Economics

Conventional economic measures of natural resource values have frequently focused on, for example, board-feet sales from timber harvests or kilowatts of electric power production. The measures are incorporated into the calculus of the Nation's economic activity such as the gross domestic product (GDP) and the gross national product (GNP). Such economic measures are frequently used in the shaping of national policies and directions showing, for example, the tangible national and regional private business wealth.

Pollution of rivers, soil erosion, destruction of wildlife, noise and other such business byproducts have been viewed as social costs or "externalities" which means their costs are not subtracted from the calculation of the nation's business wealth²². In part, they have been treated as externalities due to the lack of or the imprecise measures of their monetary costs²³. Recent events are beginning to alter these conventional views.

The Department's natural resource damage assessment regulations contain procedures and economic methodologies to allow natural resource agencies to recover monetary damages from polluters for losses to both commodity and noncommodity resources²⁴. The Bureau of Economic Analysis (BEA) within the Department of Commerce has been directed by President Clinton, as part of his Earth Day address, to develop "Green GDP" measures to highlight the economy's use of natural and environmental resources²⁵. Further, there is growing awareness within the economics profession of the need for improving the way the Nation's endowment of natural resources are considered in relation to the economy²⁶. The National Biological Survey is also initiating programs to develop and refine economic methodologies for measuring natural resource values.

The Bureau of Land Management, as part of its FY95 budget, has expressed its commitment to bring noncommodity resources on par with commodity resources. The inventory requirements of FLPMA 201(a) also require the Bureau to prepare and maintain on a continuing basis an inventory of public lands and their resources and values (emphasis added). The activities identified above will likely be of assistance to the Bureau in meeting its resource valuation commitments. *The Bureau should develop formal and informal ties with the above noted organizations to gain improved understanding of ongoing resource valuation activities; and should specifically request the National Biological Survey to assist in the development of appropriate measures of BLM's resource values for use at the national, ecoregion, and local area levels.*

Societal Interactions

People are an integral part of ecosystems. The biological and physical components of ecosystems interact with the cultural and social makeup of society. As such, societal interactions will be a key element to measure for ecosystem management.

Considerations of these interactions cannot be disregarded in resource management decision making. A recent example is the proposals and decisions to reduce the rate of harvesting old growth timber in the Pacific Northwest. Another example is the acceptance of natural events, such as wildfires, as a method to attain desired biodiversity of vegetation and creating vegetative successions and edge effects.

The Bureau's measurements of societal interactions will need to include both the resource responses and the social effects. Some examples of the types of measures that may be relevant include: changes in demographic populations and the average income levels, new housing starts, current business data (e.g., agriculture, mining, manufacturing, public utilities, and transportation). Such information is available through the Bureau of Census²⁷ and other local and state governments, and Chamber of Commerce reports and statistics.

Interagency Management Coordination

In complex, multiuse systems, management is widely divested among agencies and political jurisdictions. Ecosystem management must account for divested management authorities, regulations, controls, and property interests. For example, public-managed natural resources are referenced in the Comprehensive Environmental Response, Compensation, and Liability Act as those which "belong to, managed by, held in trust by, appertaining to, or otherwise controlled by" Federal and state agencies, and Indian tribes. In numerous instances, the actions of one agency or jurisdiction will affect the interests of another. Interagency coordination of management actions is critical.

The Bureau's planning and management framework represented in Figure 1 highlights the expanse of interagency involvement and coordination that is to occur in ecosystem management activities. Coordination is required for establishing common ecosystem management goals, strategies and plans; and the conduct of joint assessments. Lacking a common management goal could potentially result in the respective goals being in conflict with neither being achieved. Through improved interagency coordination and the conduct of joint assessments, technical and scientific data will be shared to avoid unnecessary duplication and to reduce the assessment costs. Also, there is a greater likelihood that a greater range of technical and scientific expertise as a result of the combined forces. Problems of incompatible data sets, different findings and conflicting conclusions are minimized.

ECOSYSTEM CONSIDERATIONS

General considerations for ecosystem information and data-collections oftentimes include measures of their climate, structure, composition, productivity, animal life, and nutrient cycling. In addition, it may be appropriate to include measures of ecosystem function, biodiversity, and ecosystem limits.

Ecosystem Functions

Ecosystem function is the flow of energy, materials, species, nutrients, and other elements through time and space. Important ecological functions are the integrators of ecosystems and often dominate and control their composition and structure.

Nutrient cycling and other aspects of turnover; productive ecosystems; disturbance regimes such as fire, flood and disease; and movement of animals and plants within and between ecosystems are examples of ecosystem functions. The measurement of ecosystem functions may need to be incorporated into assessments conducted at the ecoregion and local area levels.

A healthy and vigorous ecosystem should respond to natural events such as wildfires. In these ecosystems the release of energy caused by wildfires can have a positive affect on the reintroduction of native vegetation and animals. A key measurement of health may be the vigor of new plant communities. The introduction of seral successions and the reintroduction of native flora and animal populations, both vertebrates and invertebrates, should be some of the indicators of desired results.

Past management and analysis of ecological systems have tended to focus on the composition of ecosystems. That is, the presence and absence of particular component parts. Some effort has also dealt with their structure. Important processes or functions have had less attention. *The Bureau of Land Management should encourage the National Biological Survey to conduct additional research into how to portray and understand ecological functions.*

Biodiversity

Biodiversity is a key measurement for ecosystem management. Biodiversity is a key indicator for ecosystem quality, health and vigor. Diversity should be measured in terms of physical, biological and chemical responses within the ecosystems. For example, the physical properties of the soil, including the soil chemical properties and the soil structure, must be scientifically measured and documented. The diversity of the biological

communities must include the consideration of soil fertility, the availability and quality of groundwater and the health of all wildlife populations.

Measurements of biodiversity will depend on the potential of an ecosystem. Biodiversity must be dynamic and fluid to achieve levels of desired ecosystem fertility and stability. Biodiversity will need to be measured by its longevity. For example, prairie dog towns should thrive for centuries not just for a few years or decades. As the population of the prairie dog town fluctuates so will the populations of other macro- and microorganisms that depend on the biological processes that are associated with prairie dog communities.

The results should be measured in terms of time required to achieve desired mixtures of plant and animal life and populations, and the success of achieving soil fertility, reintroduction of native vegetation, and the trend from xeric to moist and wet habitats.

Ecosystem Limits

Ecological systems have limits. The functions noted above control the ecosystem composition and structure within these limits. However, there is currently insufficient understanding as to when these limits have been exceeded by management actions. If the Bureau manages for conditions that exceed these limits, then major alterations to the ecological setting may result. Costs and risks will increase markedly and will take considerable time and effort to keep the activity in balance with the lands capability.

There are also a variety of risks associated with departing from commonly expressed conditions. For example, maintaining a cover of trees for visual effect by fire suppression, in an area that naturally burns frequently, may increase the risk of an eventual catastrophic fire. Managers and, more importantly, the public need to recognize these potential costs and risks. *For these reasons, the Bureau should initiate discussions with the National Biological Survey and other research organizations to identify those predominant factors influencing ecosystem limits.*

INFORMATION AND DATA NEEDS

Although the precise information and data sets needed for implementing ecosystem management within the Bureau are not yet known, it is reasonable to begin compiling descriptions of the general types that will be needed. These descriptions have been compiled in Table 1 which follows. The descriptions have been developed by asking the following specific questions pertinent to Figures 1 and 2:

1. What are the general types of management decisions that need to be made at each of the national, ecoregion, and local area levels?; and,
2. What are the general types of information and data needed to support each of the management decisions?

Table 1. Bureau of Land Management's corporate information and data needs for ecosystem management.

ORGANIZATIONAL LEVEL	MANAGEMENT RESPONSIBILITY	INFORMATION AND DATA NEEDS
National	<ul style="list-style-type: none"> ■ Set national policy ■ Define national objectives ■ Establish procedures and regulations ■ Allocate resources by ecoregion ■ Report to Congress ■ Coordinate with national public interest groups ■ Coordinate with other Federal agencies ■ Perform national level strategic planning ■ Review and interpret legislation and regulations 	<ul style="list-style-type: none"> ■ National data aggregation at the ecosystem level <ul style="list-style-type: none"> ● Current resource status (condition, distribution, quantity and trend) <ul style="list-style-type: none"> - Renewable - Nonrenewable - Socioeconomic - Financial/personnel ● Land ownership <ul style="list-style-type: none"> - Political - Administrative - Current uses - Current restrictions - Land pattern adjustments ■ Current management objectives (Federal and state) ■ Ecosystem performance measures for long-term national management objectives ■ Ecosystem carrying capacity/Ecosystem limits (e.g., % of optimum)

Table 1. Bureau of Land Management's corporate information and data needs for ecosystem management.

ORGANIZATIONAL LEVEL	MANAGEMENT RESPONSIBILITY	INFORMATION AND DATA NEEDS
Ecoregion	<ul style="list-style-type: none"> ■ Implement national policy ■ Implement national strategic plans ■ Develop ecoregion goals ■ Allocate resources to meet goals and priorities ■ Evaluate progress in meeting goals and priorities ■ Recommend policy changes ■ Coordinate with ecoregion and special interests ■ Coordinate with state and local federal agencies ■ Conduct resource management planning 	<ul style="list-style-type: none"> ■ Ecoregion data aggregation at the local area level <ul style="list-style-type: none"> ● Current resource status (condition, distribution, quantity and trend) <ul style="list-style-type: none"> - Renewable - Nonrenewable - Socioeconomic - Financial/personnel ● Land ownership <ul style="list-style-type: none"> - Political - Administrative - Current uses - Current restrictions - Land pattern adjustments ■ Current management objectives (State and local) ■ Ecosystem performance measures for long-term national management objectives ■ Ecosystem carrying capacity/Ecosystem limits (e.g., % of optimum)

Table 1. Bureau of Land Management's corporate information and data needs for ecosystem management.

ORGANIZATIONAL LEVEL	MANAGEMENT RESPONSIBILITY	INFORMATION AND DATA NEEDS
Local Area	<ul style="list-style-type: none"> ■ Develop and execute local implementation plans ■ Utilize financial and personnel resources to accomplish plan ■ Monitor and evaluate accomplishments ■ Revise and update plans ■ Develop local partnerships with city and county agencies ■ Conduct inventory and monitoring of local area renewable and nonrenewable resources 	<ul style="list-style-type: none"> ■ Data compilation at the local area level <ul style="list-style-type: none"> ● Current resource status (condition, distribution, and quantity) <ul style="list-style-type: none"> - Renewable - Nonrenewable - Socioeconomic - Financial/personnel ● Land ownership <ul style="list-style-type: none"> - Political - Administrative - Current uses - Current restrictions - Land pattern adjustments ■ Current management objectives (Local area)

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